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**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
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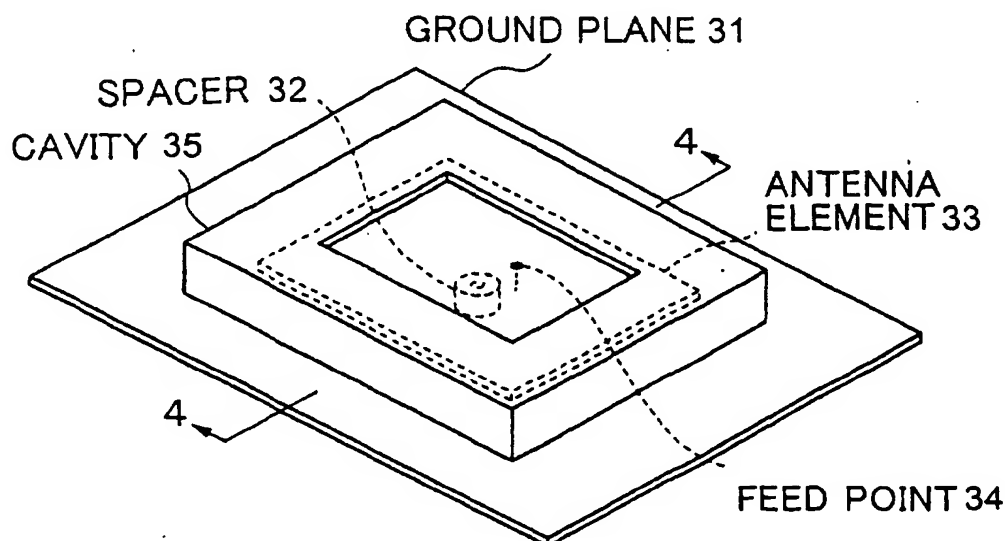
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(54) **Planar antenna device**

(57) A planar antenna device comprises a ground plane (31), a planar antenna element (33) having a principal plane mounted above the ground plane, and a cavity (35) having an opening partially exposing the antenna element, placed on the ground plane in order to cover the entire antenna element contactlessly.



**FIG. 3**

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# EUROPEAN SEARCH REPORT

Application Number  
EP 00 31 1294

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (InLCI.7)
X	US 4 242 685 A (SANFORD GARY G) 30 December 1980 (1980-12-30) * abstract; figures 1-3,5 *	1-4,6	H01Q9/04
Y	---	5	
X	US 4 131 894 A (SCHIAVONE FRANK J) 26 December 1978 (1978-12-26) * the whole document *	1,2,4,6	
Y	---	5	
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 504 (E-1430), 10 September 1993 (1993-09-10) -& JP 05 129823 A (SONY CORP), 25 May 1993 (1993-05-25) * abstract *	1,2,4,6	
X	* figure 13 *	5	
X	KARMAKAR N ET AL: "Investigations into a circular patch antenna in a cylindrical cavity enclosure", SINGAPORE ICCS '94. CONFERENCE PROCEEDINGS. SINGAPORE 14-18 NOV. 1994, NEW YORK, NY, USA, IEEE, US, PAGE(S) 446-450 XP010150032 ISBN: 0-7803-2046-8 * figure 1 *	1,2,4,6	TECHNICAL FIELDS SEARCHED (InLCI.7)
X	JELLETT S T ET AL: "The design of a shielded, dual patch antenna array element for mobile satellite communications", ANTENNAS AND PROPAGATION SOCIETY INTERNATIONAL SYMPOSIUM, 1993. AP-S. DIGEST ANN ARBOR, MI, USA 28 JUNE-2 JULY 1993, NEW YORK, NY, USA, IEEE, PAGE(S) 140-143 XP010132878 ISBN: 0-7803-1246-5 * page 140, paragraph 5 - page 141, paragraph 2 *	1,2,4,6	H01Q
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 23 December 2002	Examiner Marot-Lassauzaie, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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Application Number  
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	GB 2 054 275 A (EMI LTD) 11 February 1981 (1981-02-11) * figure 1B *	1,2,4,6	
X	US 5 608 263 A (DRAYTON RHONDA F ET AL) 4 March 1997 (1997-03-04) * abstract; figure 1 *	1,2,4,6	
X	US 6 049 309 A (TIMOSHIN VLADIMIR G ET AL) 11 April 2000 (2000-04-11) * figures 1,2 *	1,2,4,6	
Y	EP 0 996 192 A (HARADA IND CO LTD) 26 April 2000 (2000-04-26) * paragraph [0015]; figure 1B *	5	
A	* figure 1C *	1-4,6	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
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<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone  Y : particularly relevant if combined with another document of the same category  A : technological background  O : non-written disclosure  P : intermediate document</p> <p>T : theory or principle underlying the invention  E : earlier patent document, but published on, or after the filing date  D : document cited in the application  L : document cited for other reasons  &amp; : member of the same patent family, corresponding document</p>			

EPO FORM 1503 (3-92) (P04001)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 00 31 1294

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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23-12-2002

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4242685	A	30-12-1980	DE 3066230 D1	01-03-1984
			EP 0018476 A1	12-11-1980
			IN 153631 A1	28-07-1984
			JP 1497088 C	16-05-1989
			JP 55145403 A	13-11-1980
			JP 63040364 B	10-08-1988
US 4131894	A	26-12-1978	DE 2816362 A1	19-10-1978
			FR 2387527 A1	10-11-1978
			GB 1594559 A	30-07-1981
			JP 53129567 A	11-11-1978
			NL 7803816 A	17-10-1978
JP 05129823	A	25-05-1993	NONE	
GB 2054275	A	11-02-1981	DE 3023055 A1	05-02-1981
			FR 2461373 A1	30-01-1981
			US 4369447 A	18-01-1983
US 5608263	A	04-03-1997	US 5913134 A	15-06-1999
US 6049309	A	11-04-2000	NONE	
EP 0996192	A	26-04-2000	JP 2000124734 A	28-04-2000
			EP 0996192 A2	26-04-2000
			KR 2000029161 A	25-05-2000
			TW 434941 B	16-05-2001
			US 6208298 B1	27-03-2001



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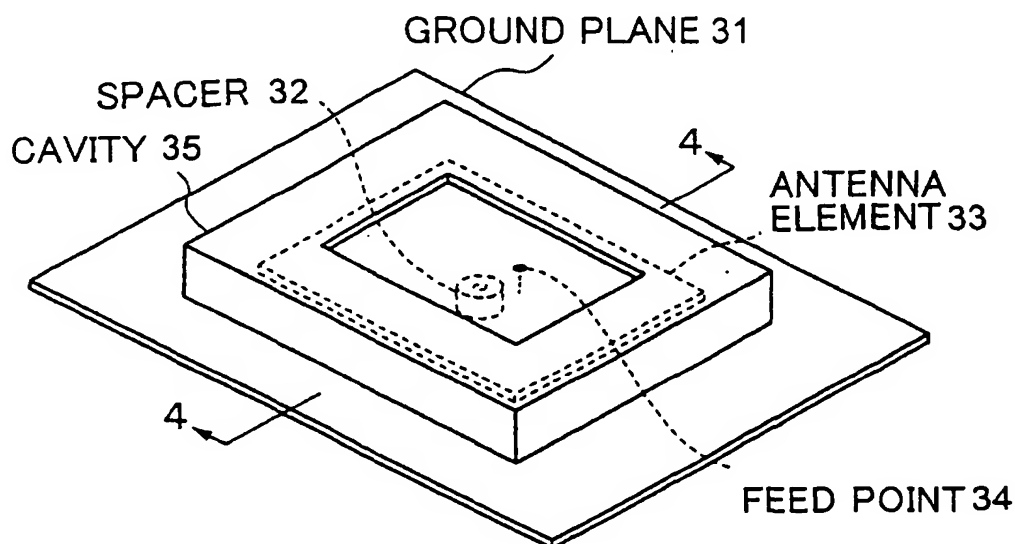


FIG. 3

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## Descripti n

**[0001]** The present invention relates to an on-vehicle planar antenna device for receiving satellite broadcasting.

**[0002]** Conventionally, there has been no technique but decreasing an antenna element size when a planar antenna device is used for obtaining high electro-magnetic field radiation characteristics within the range of a wide elevation angle.

**[0003]** FIG. 1 illustrates a structure of a general air patch antenna device. FIG. 1 shows a ground plane 11, an antenna element 12 mounted on the ground plane 11 separated by a spacer 13, and a feed point 14 to the antenna element 12.

**[0004]** A microstrip antenna device stationed in the air ( $\epsilon r = 1$ ) has a high relative antenna device gain. On the other hand, however, the half-power angle generally becomes approximately  $60^\circ$  to  $80^\circ$  depending on antenna device shapes. Consequently, a gain remarkably decreases toward a low elevation angle.

**[0005]** To decrease the antenna element size for widening such a narrow elevation angle range, a dielectric must be used.

**[0006]** FIG. 2 illustrates an example structure of a dielectric patch antenna device using the dielectric. FIG. 2 shows a ground plane 21, a dielectric plate 22 mounted on the ground plane 21, an antenna element 23 provided on the dielectric plate 22, and a feed point 24 to the antenna element 23.

**[0007]** The size of the antenna element 23 is decreased by using the dielectric plate 22. It becomes possible to obtain high electromagnetic field radiation characteristics within a wide elevation angle range.

**[0008]** However, the antenna element size is decreased for the dielectric patch antenna device in FIG. 2. Compared to the air patch antenna device in FIG. 1, the antenna device gain greatly decreases. In addition, a loss due to the dielectric plate 22 further decreases the antenna device gain. As a result, the dielectric patch antenna device in FIG. 2 does not provide so high a radiation level toward a low elevation angle.

**[0009]** An object of the present invention is to provide a planar antenna device which satisfies both of electromagnetic field radiation characteristics over a wide elevation angle range including a low elevation angle direction and a high antenna device gain.

**[0010]** A planar antenna device according to the present invention comprises: a ground plane; a planar antenna element having a principal plane mounted above the ground plane; and a cavity, having an opening partially exposing the antenna element, placed on the ground plane in order to cover the entire antenna element contactlessly.

**[0011]** Preferred manners for the above-mentioned planar antenna device are as follows.

(1) A feed point for supplying power supply to the

antenna element is further provided.

(2) An area of the opening is smaller than a size of the antenna element.

(3) The opening is placed substantially parallel to a principal plane of the antenna element.

(4) The antenna element is an air patch antenna element mounted above the ground plane separated by a spacer.

**[0012]** Another planar antenna device according to the present invention comprises a ground plane; a planar antenna element having a principal plane mounted above the ground plane; and a planar conductor placed substantially parallel to a principal plane of the antenna element and having an opening at substantially a center thereof.

**[0013]** According to the present invention, it is possible to provide excellent electromagnetic field radiation characteristics over a wide elevation angle range including a low elevation angle direction and a high antenna device gain only by adding a cavity to a conventional air patch antenna device without decreasing the antenna element size, thereby maintaining sufficiently high antenna device gain.

**[0014]** Further, the present invention eliminates the need to use a dielectric for obtaining a gain toward a low elevation angle. It is possible to maintain a high antenna device gain without decreasing an antenna device gain due to a dielectric loss.

**[0015]** This summary of the invention does not necessarily describe all necessary features so that the invention may also be a sub-combination of these described features.

**[0016]** The invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective view exemplifying a structure of a conventional air patch antenna device;

FIG. 2 is a perspective view exemplifying a structure of a conventional dielectric patch antenna device;

FIG. 3 is a perspective view illustrating a structure of an antenna device according to an embodiment of the present invention for receiving BS digital broadcasting;

FIG. 4 is a sectional view of an antenna device structure taken along the line 4-4 of FIG. 3;

FIG. 5 shows VSWR characteristics of an antenna device according to an embodiment of the present invention;

FIG. 6 shows return loss characteristics of an antenna device according to an embodiment of the present invention;

FIG. 7 is a Smith chart for an antenna device according to an embodiment of the present invention; FIG. 8 shows gain characteristics of an antenna device according to an embodiment of the present invention in comparison with conventional antenna

devices corresponding to azimuth angles at a horizontal plane;

FIGS. 9A through 9C show directivities of an antenna device according to an embodiment of the present invention and conventional antenna devices; and

FIG. 10 is a modification of an antenna device according to the present invention.

**[0017]** An embodiment of the planar antenna device according to the present invention will be described in further detail with reference to the accompanying drawings.

**[0018]** FIG. 3 is a perspective view illustrating a structure of a planar antenna device according to the present invention. FIG. 4 is a sectional view taken along the line 4-4 of FIG. 3.

**[0019]** In FIG. 3, an antenna element 33 is mounted above a ground plane 31 via a spacer 32 so that the antenna element 33 is separated from the ground plane 31. This antenna element 33 is excited by power from the feed point 34. The ground plane 31 is made of a metal plate such as brass, aluminum, stainless steel, and the like. The spacer 32 is made of synthetic resin such as polyacetal, polycarbonate, ABS, and the like. The antenna element 33 is made of a metal plate such as brass, aluminum, and the like.

**[0020]** A box-like cavity 35 is placed on the ground plane 31 so as to cover the entire antenna element 33. The cavity 35 is made of a metal plate such as brass, aluminum, and the like.

**[0021]** The cavity 35 is provided so that it does not touch the antenna element 33 with a predetermined distance. A square opening 35a, which is smaller than a size of the antenna element 33, is formed at a surface a cavity 35 which is opposite to the antenna element 33.

**[0022]** The opening 35a of this cavity 35 is formed in order to provide high electromagnetic field radiation characteristics in a wide range of elevation angles, especially toward a low elevation angle without reducing the size of the antenna element 33. It is possible to change electromagnetic field radiation characteristics especially toward a low elevation angle by adjusting the size of the opening 35a with reference to the antenna element 33 and a distance between the opening 35a and the antenna element 33.

**[0023]** In the above-mentioned antenna device structure, various characteristics observed from experiments will be described as follows.

**[0024]** First, characteristics of the antenna device itself will be described with reference to FIGS. 6 through 7.

**[0025]** FIGS. 5 through 7 show an experimental voltage standing-wave ratio (VSWR), a return loss corresponding to the VSWR, and a Smith chart, respectively. Any of the characteristics FIGS. 5 through 7 indicates that an excellent performance is available at approximately 2.34 GHz with an input impedance of 50Ω.

**[0026]** FIGS. 8 through 9C exemplify characteristics of the antenna device according to the embodiment of the present invention in comparison with the air patch antenna device in FIG. 1 and the dielectric patch antenna device in FIG. 2.

**[0027]** FIG. 8 shows gain characteristics corresponding to azimuth angles at a horizontal plane. A characteristic  $\alpha$  indicated by a thin line corresponds to the air patch antenna device in FIG. 1. A characteristic  $\beta$  indicated by a broken line corresponds to the dielectric patch antenna device in FIG. 2. A characteristic  $\gamma$  indicated by thick lines corresponds to the antenna device with the cavity 35 in FIGS. 3 and 4 according to this embodiment.

**[0028]** As shown in FIG. 8, the air patch antenna device showing the characteristic  $\alpha$  provides a high gain at around azimuth angle 0°, but causes large gain changes corresponding to azimuth angles. The air patch antenna device in FIG. 8 is found to be inappropriate for, especially, an on-vehicle antenna device which always changes antenna device angles according to directions of radio waves received.

**[0029]** The dielectric patch antenna device showing the characteristic  $\beta$  decreases the antenna element size and causes a dielectric loss, decreasing the total gain for the entire antenna device.

**[0030]** By contrast, the antenna device according to this embodiment showing the characteristic  $\gamma$  causes a little change in gains according to azimuth angles and is found to be suited for an antenna device which always changes antenna device angles in accordance with directions of radio waves received.

**[0031]** FIGS. 9A through 9C show directivities of the antenna devices explained in FIG. 8.

**[0032]** FIG. 9A exemplifies a directivity of the air patch antenna device. The directivity is valid only in a front direction and within a high elevation angle range. It is understood that the directive range is very narrow.

**[0033]** FIG. 9B exemplifies a directivity of the dielectric patch antenna device. Compared to the air patch antenna device in FIG. 9A, the dielectric patch antenna device in FIG. 9B increases a characteristic at the azimuth angle and toward a low elevation angle. However, it is understood that the directivity is unsatisfactory.

**[0034]** FIG. 9C exemplifies a directivity of the antenna device with the cavity 35 according to this embodiment. The antenna device in FIG. 9C provides the directivity in a very wide range not only at the azimuth angle on the horizontal plane, but also at elevation angles especially ranging from low to high elevation-angle directions.

**[0035]** As mentioned above, the antenna device structure with the cavity 35 according to this embodiment of the present invention can maintain high electromagnetic field radiation characteristics over a wide elevation angle range from a low elevation-angle direction. It is also possible to provide a sufficiently high total gain for the entire antenna device.

[0036] Compared to a quadrifilar helical antenna device, a cross di-pole antenna device, and the like having high efficiency and low elevation-angle radiation characteristics, the antenna device according to this embodiment of the present invention provides the following advantages.

- (1) Simplifying a structure of the entire antenna device including a feed structure.
- (2) Providing a mechanically solid structure having the rigid cavity for guarding the antenna element with no sharp projections.
- (3) Easily manufacturing the antenna device.
- (4) Easily thinning the entire antenna device structure.

[0037] The antenna device according to the present invention can be easily mass-produced and be suitably mounted on vehicles such as cars.

[0038] The above-mentioned embodiment provides an air patch antenna device with the cavity 35. The present invention is not limited thereto.

[0039] For example, in the embodiment, an elevation radiation characteristic is improved by providing the cavity, but a rectangular conductor 36 having an opening (or may be a circular conductor, or a linear conductor like a wire etc.) as shown in FIG. 10 may be provided like the cavity 35. That is, any conductor may be used to define an aperture of the antenna. With this configuration, the same advantage can be obtained as the above-mentioned embodiment.

[0040] The present invention is not limited to above-mentioned embodiment, and can be achieved in a scope of the invention.

## Claims

1. A planar antenna device **characterized by** comprising:

a ground plane (31);  
a planar antenna element (33) having a principal plane mounted above said ground plane;  
and  
a cavity (35), having an opening partially exposing said antenna element, placed on said ground plane in order to cover said entire antenna element contactlessly.

2. The planar antenna device according to claim 1, **characterized by** further comprising a feed point (34) for supplying power supply to said antenna element.

3. The planar antenna device according to claim 1 or 2, **characterized in that** an area of said opening is smaller than a size of said antenna element.

4. The planar antenna device according to any one of claims 1, 2, or 3, **characterized in that** said opening is placed substantially parallel to a principal plane of said antenna element.

5. The planar antenna device according to any one of claims 1, 2, 3, or 4, **characterized in that** said antenna element is an air patch antenna element mounted above said ground plane separated by a spacer (32).

6. A planar antenna device **characterized by** comprising:

a ground plane (31);  
a planar antenna element (33) having a principal plane mounted above said ground plane;  
and  
a conductor (36) placed substantially parallel to a principal plane of said antenna element and having an opening at substantially a center thereof.



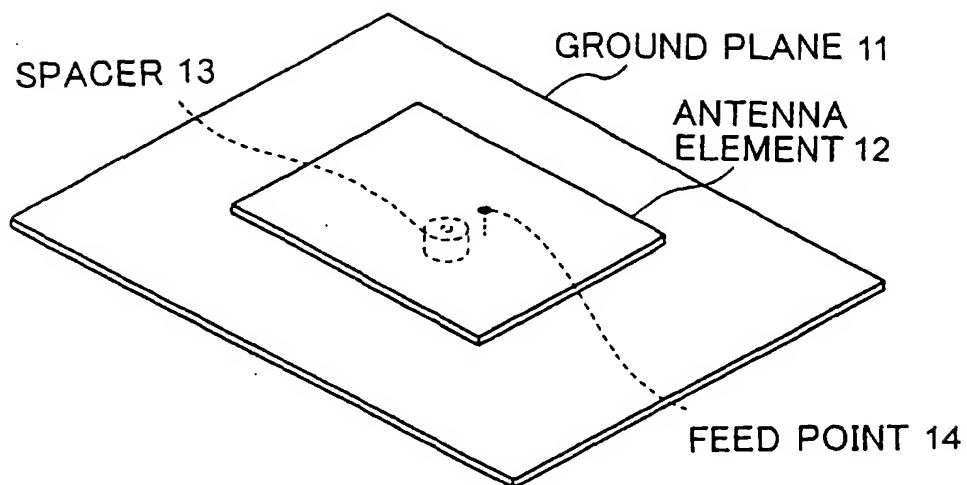


FIG. 1

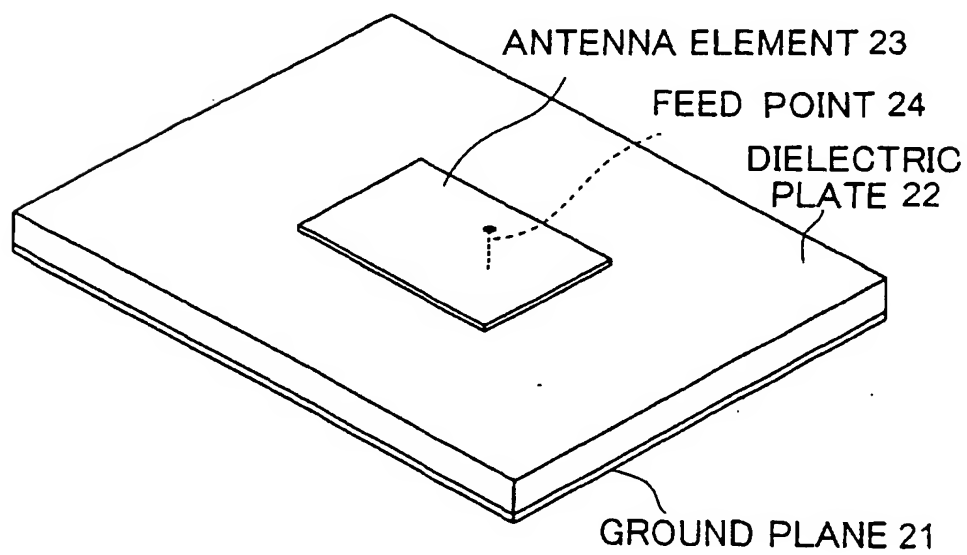


FIG. 2

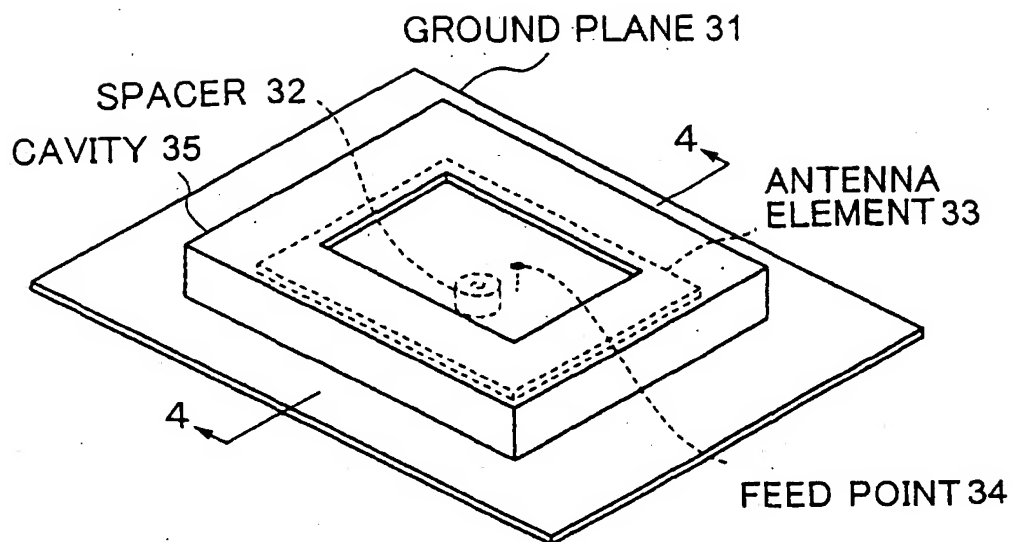


FIG. 3

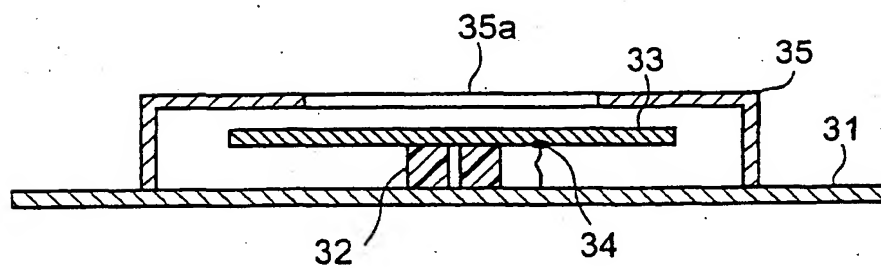


FIG. 4

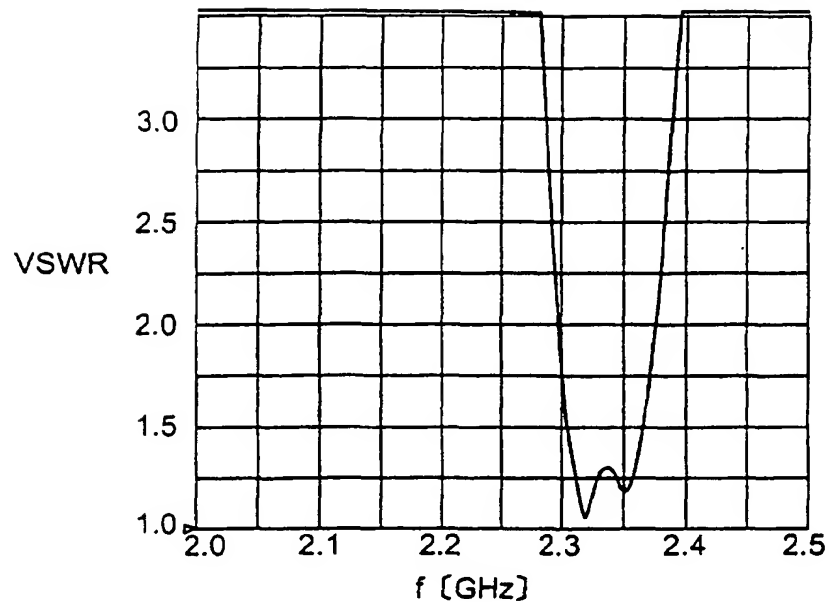


FIG. 5

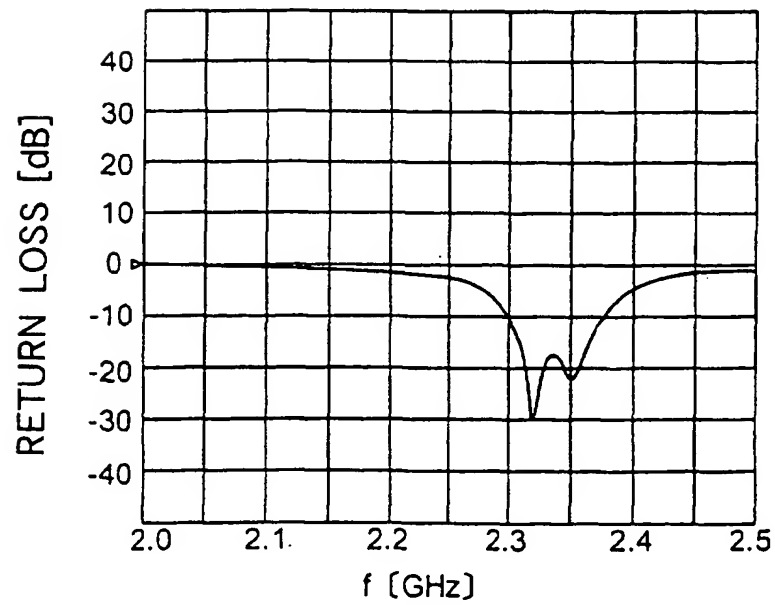


FIG. 6

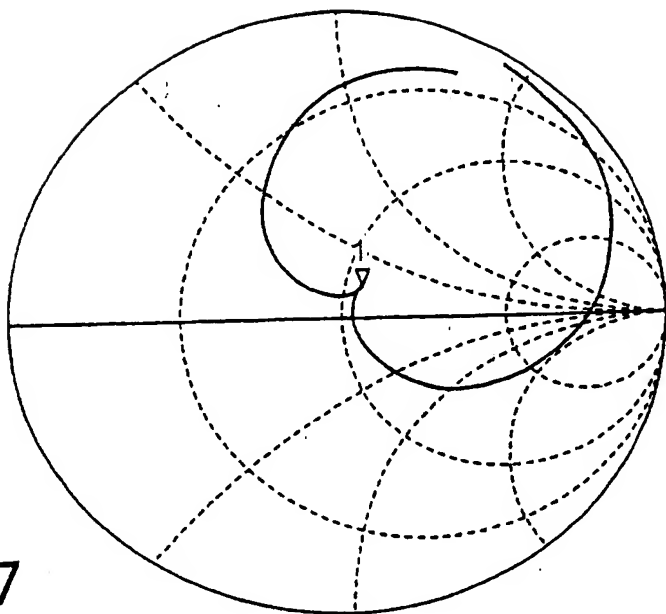


FIG. 7

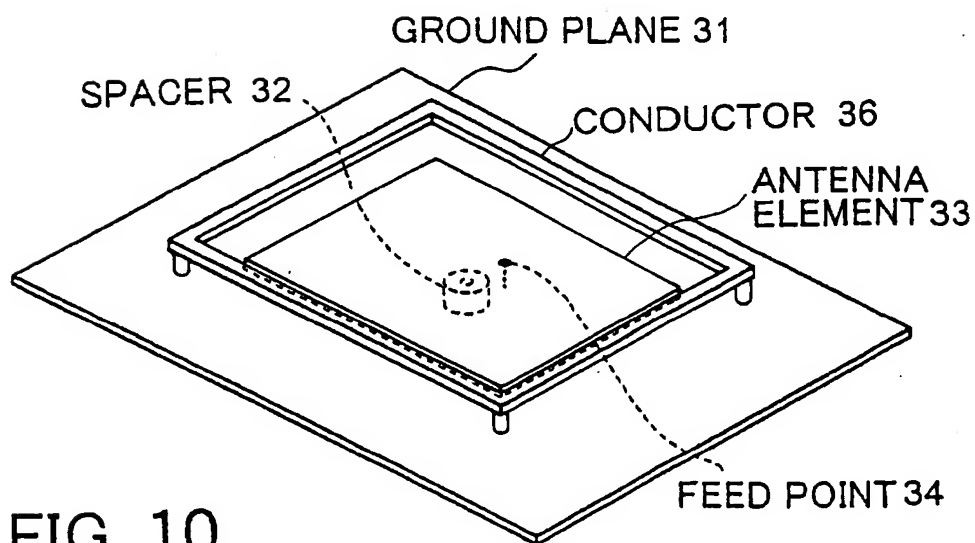
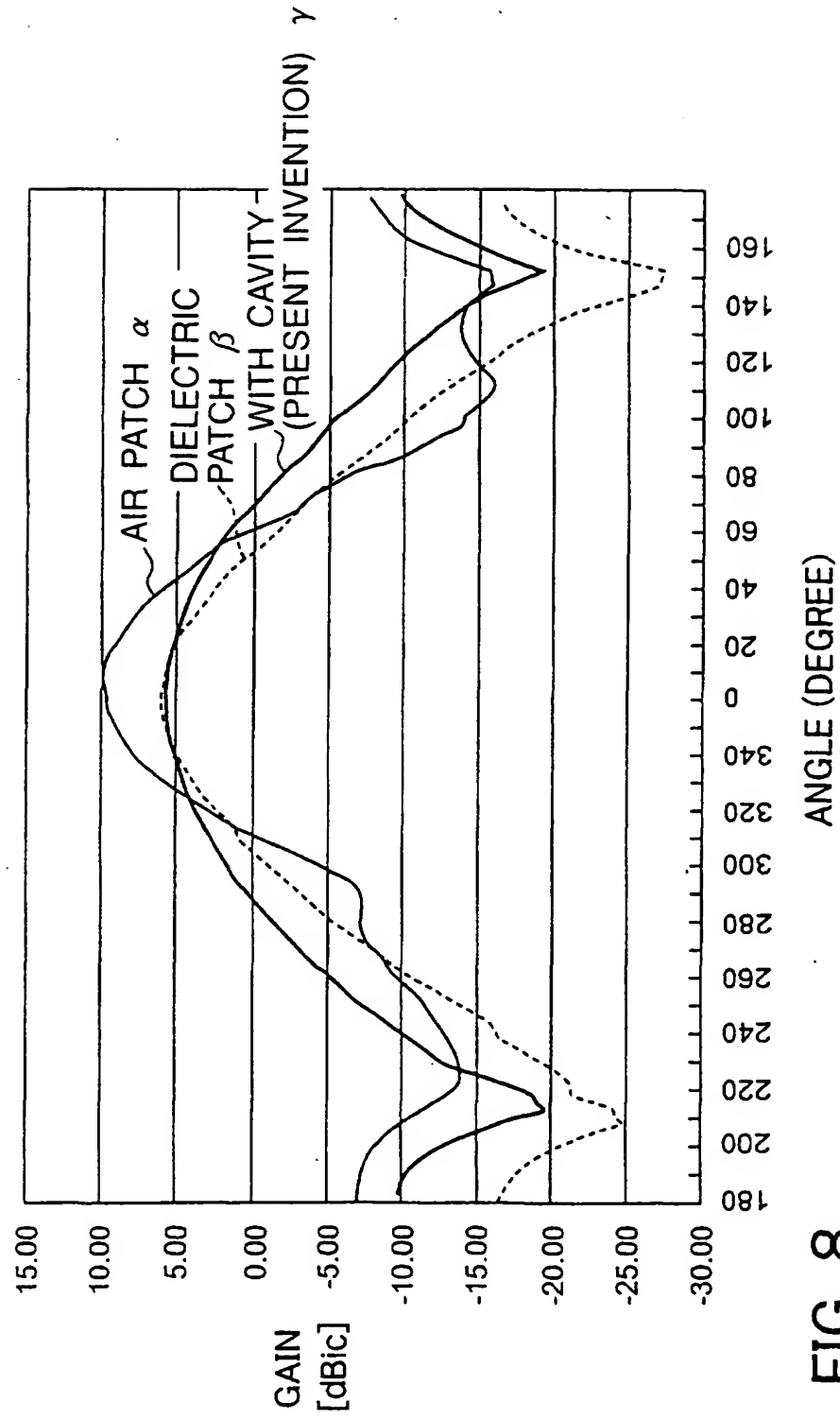


FIG. 10



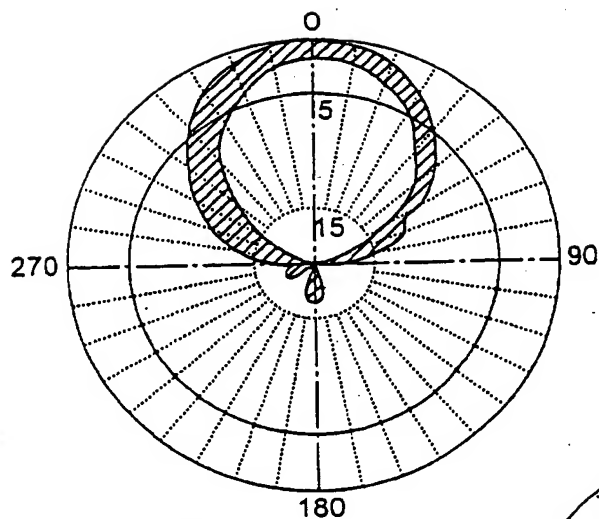


FIG. 9A

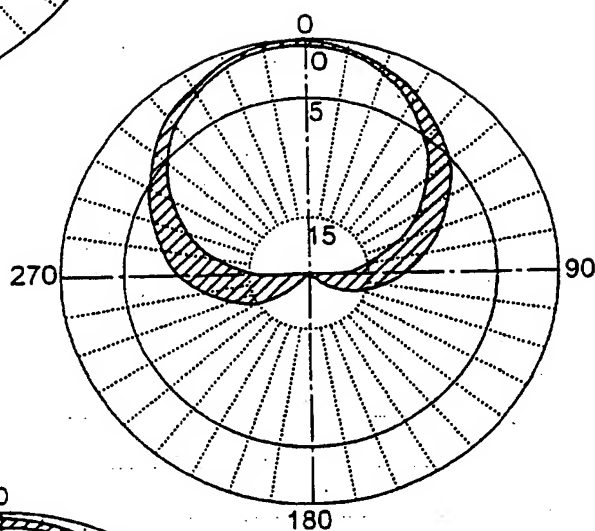


FIG. 9B

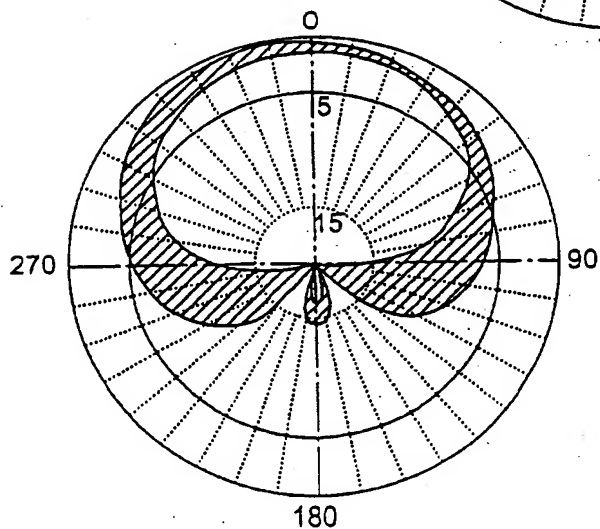


FIG. 9C